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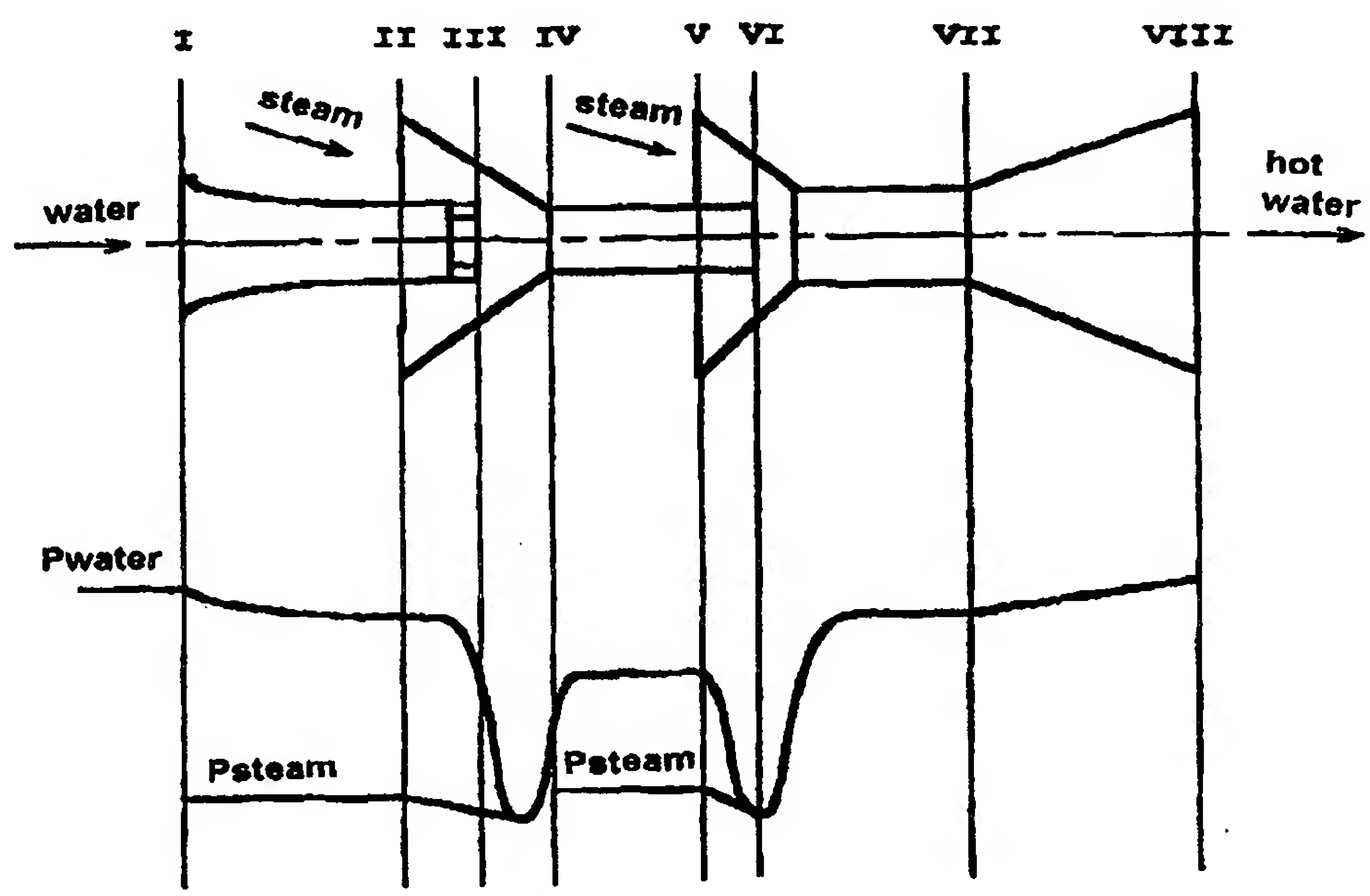
(54) Title: METHOD FOR OBTAINING A TWO–PHASE SUPERSONIC FLOW WITH HEAT SUPPLY IN JET PUMP PLANT

(57) Abstract




A method of operation of a jet apparatus, including feeding at least one liquid heat carrier under pressure into a nozzle, feeding of a cold liquid heat carrier and their mixing, characterized in that two conversions are carried out with the liquid flow of the heat carrier mixture, one of them including an acceleration of the heat carrier mixture to a velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of a two–phase flow with the transfer of the latter to conditions with a Mach number of more than 1, and then a sudden change of pressure with the transfer in the latter of the two–phase flow to a subsonic liquid flow of the heat carrier mixture and heating the liquid flow of the heat carrier mixture during the sudden change of pressure being performed; another conversion including the acceleration of the liquid flow of the heat carrier mixture to a velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two–phase flow with the transfer of the latter to the conditions with a Mach number equal to 1, then the two–phase flow being decelerated, and thereby the flow being converted into the liquid flow of the heat carrier mixture with vapour–gas bubbles, and additionally, by this flow conversion, the liquid flow of the heat carrier mixture being heated; thereafter carrying out said two above–mentioned conversions of the liquid flow of the heat carrier mixture in any sequence, the heated liquid flow of the heat carrier mixture being fed under the pressure obtained in the jet apparatus to a consumer.

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# METHOD FOR OBTAINING A TWO-PHASE SUPERSONIC FLOW WITH HEAT SUPPLY IN JET PUMP PLANT

## Technological area

The invention belongs to the field of jet technology, preferably to jet apparatuses, wherein the process of heating a pumped and ejected medium can be performed.

## The prior art

The method of operation of a heat emitting jet apparatus is known, including feeding a liquid heat carrier into a nozzle of a jet apparatus, its mixing with a cooled heat carrier, feeding of the mixture into a device for transforming kinetic energy of the flow into thermal energy of the liquid and subsequently feeding of the heated liquid medium into the heat emitting device (refer to SU author's certificate 306322, class F 25 B 29/00, 1971).

However, this method has a low efficiency which is related to large energy expenditures for pumping the liquid medium through the device for transforming kinetic energy into thermal energy, in connection with which these devices were not widely used.

The method of operation of a heat emitting jet apparatus is also known, including feeding a heated heat carrier into the nozzle under pressure, feeding a cold liquid heat carrier and their mixing (refer to SU author's certificate 1290015, class F 04 F 5/02, 1987).

In this method of operation of the jet apparatus, heating the heat carrier is performed exclusively on the basis of a heat transfer from the heated heat carrier to the cooled one. In this method of operation, the energy of the heat carrier itself, in particular kinetic energy, is not used, which decreases the efficiency of operation of this jet apparatus to a considerable degree.

The method of compressing a medium in a jet apparatus and a device for its performance are also known (refer to RU patent 2016261, cl. F 04 F 5/02, 1994). The method of operation includes feeding an active and passive medium at a subsonic velocity into the apparatus, mixing the medium in a mixing chamber with formation of a two-phase mixture and accelerating the mixture first to a subsonic velocity, and then in the expansion chamber to a supersonic velocity, performing a compression step for decelerating the mixture with the corresponding increase of static pressure after the compression step and transforming the flow into a single-phase one; here, the maximum static pressure after the compression step should be less than half the sum of the deceleration pressure after the compression step and the static pressure before the step.

When performing this method in the jet apparatus, homogeneous finely dispersed mixtures of several components are obtained. However, an essential difference between this method and the described inventive one consists in reaching supersonic operating conditions in the jet apparatuses resulting in differences in the construction of jet apparatuses. As a consequence thereof, the use of the jet apparatus operating according to this described method in autonomous heat emitting apparatuses will be less effective.

A method of operation of a jet apparatus for regenerative heating of water is known, including feeding steam into a turbogenerator, taking the steam from the turbogenerator, taking the processed last steam from the turbogenerator into a condenser, feeding the condensate from the condenser and the steam taken from the turbogenerator, into the jet apparatus with the condensation of the steam in the jet apparatus and heating said condensate by subsequently feeding the heated condensate as feed water in a deaerator and then into a boiler-steam generator (refer to the book "The general heat technology", edited by Kornitski S.Ya. and Rubinstein Ya. M., M., The State Energy Publishing House). The replacement of the surface heater type by a heater of the mixing type in this case did not lead to the anticipated positive

result, because the jet apparatuses used in this method had large dimensions, operated unstably and unreliably and demanded large energy expenditures, as an installation of a separate pump for pumping the water was required.

Jet plants are known as well, containing a jet apparatus with a receiving piece and a receiving chamber, a mixing chamber and a nozzle coaxially therewith, in which the receiving piece is connected to the receiving chamber (refer to application DE 23 30 502, cl. F 04 F 5/48, 1975).

In this application DE 23 30 502, a method of operation of a jet plant is described, including feeding a hot heat carrier under pressure into the nozzle of the jet apparatus, its outflow from the nozzle and pumping out a cold heat carrier by subsequently mixing them and forming a heated flow of the mixture of heat carriers at the outlet of the jet apparatus.

In this plant and method of operation, by bypassing the mixture of the hot and cold heat carriers downstream of the heat consuming device, a possibility of regulating the operating conditions of the jet plant is achieved. However, the regulation is provided by throttling the hot heat carrier at the outlet of the nozzle and throttling the feed of the mixture of the heat carriers in the receiving chamber of the jet apparatus, which leads to large hydraulic losses and requires the use of a complicated system of an automatic regulation of operating conditions of the jet apparatus, which decreases the reliability of operation of the jet plant. Further, large hydraulic losses do not allow sufficiently high efficiency to be obtained.

**Description of the invention**

The object, which is to be achieved by this invention, is an increase of the operation efficiency of a jet apparatus by means of an intensification of heating of the heat carrier by a more complete use of the energy of the ejected medium - the heated heat carrier, an increase of reliability of

operation of the jet apparatus and broadening the zone of its stable operation.

This object is achieved in that in the method of operation of the jet heat emitting apparatus, including feeding of a heated liquid heat carrier into the nozzle under pressure, feeding of the cold liquid heat carrier and their mixing, two conversions are carried out with the liquid flow of the heat carrier mixture. One of them includes the acceleration of the heat carrier mixture to the velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two-phase flow with the transfer of the latter to the conditions with a Mach number of more than 1, and then a sudden change of pressure with the transfer of the latter from the two-phase flow to the subsonic liquid flow of the heat carrier mixture, whereby heating of the liquid flow of the heat carrier mixture during the sudden change of pressure is realized. Other conversions include the acceleration of the liquid flow of the heat carrier mixture to the velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two-phase flow with the transfer of the latter to the conditions with a Mach number equal to 1, then the two-phase flow is decelerated, and thereby the flow is converted into the liquid flow of the heat carrier mixture filled with microscopic vapour-gas bubbles, and additionally by means of this flow conversion, the liquid flow of the heat carrier mixture is heated. After carrying out the two above-mentioned conversions of the liquid flow of the heat carrier mixture in any sequence, the heated liquid flow of the heat carrier mixture is fed to a consumer under the pressure obtained in the jet apparatus.

It is possible to carry out additionally one or several conversions with the liquid flow of the heat carrier mixture.

Apart therefrom, the object stipulated can be achieved by means of the realization of two more embodiments of the method of operation of the heat emitting jet apparatus.

One of these operation embodiments includes feeding of the heated liquid carrier into the nozzle under pressure, feeding of the cold liquid heat carrier and their mixing, thereby the vapour being fed into the nozzle as the heated heat carrier and in the process of mixing forming the two-phase flow behind the nozzle by the vapour, the flow conditions of the two-phase flow with a Mach number of more than 1 being established. Then, the sudden change of pressure is realized with the conversion of the supersonic two-phase flow into a single-phase liquid flow of the heat carrier mixture therein and simultaneously heating the heat carrier mixture during the sudden change of pressure. Thereafter, the flow of the heat carrier mixture is accelerated to the velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of a two-phase flow, the flow conditions of the two-phase flow with a Mach number equal to 1 being established. Then, by means of the deceleration of the flow, its conversion into the liquid flow of the heat carrier mixture filled with microscopic vapour-gas bubbles with additionally heating the liquid flow of the heat carrier mixture and a pressure increase in the flow as the flow is decelerated, is realized. Thereafter, the heated liquid flow of the heat carrier mixture may be fed to a consumer under the pressure obtained in the jet apparatus.

Another embodiment includes feeding of the heated heat carrier into the nozzle under pressure, feeding the cold heat carrier and then mixing, thereby the vapour being fed into the nozzle as the heated heat carrier in the process of mixing with the cold liquid heat carrier of the two-phase flow with the formation behind the nozzle by the vapour, and the flow conditions of the two-phase flow with a Mach number equal to 1 being established. Then, by decelerating the two-phase flow, it is converted into the liquid flow of the heat carrier mixture filled with microscopic vapour-gas bubbles with heating of the flow in the process of its conversion into a liquid and a pressure increase in the flow. Thereafter, the flow of the heat carrier mixture is accelerated to the velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two-phase

flow, then the flow conditions of the two-phase flow with a Mach number of more than 1 are established, and the two-phase flow of the heat carrier mixture during the sudden change of pressure is converted into the liquid flow of the heat carrier mixture with an additional heating of the liquid flow of the heat carrier mixture during the sudden change of pressure. Thereafter, the heated liquid flow of the heat carrier mixture may be fed to a consumer under the pressure obtained in the jet apparatus.

The method and apparatus of the present invention may employ any suitable liquid and vapour. Water and steam are most suitable. Alternative liquids and vapours include ammonia, together with ammonia vapour.

The vapour herinbefore referred to is preferably steam. Thus, when using the method of operation of the jet apparatus for a regenerative heating of feed water in the jet heater, the object stipulated is achieved in that the method of operation, including feeding steam into a turbogenerator, taking the steam from the turbogenerator, the removal of the steam processed last from the turbogenerator into a condenser, feeding the condensate from the condenser and the steam, taken from the turbogenerator, into a jet apparatus-jet heater with the condensation of the steam in the jet apparatus and heating of the condensate with subsequently feeding the heated condensate as the feed water into a deaerator and then into a boiler-steam generator. Hereby, the condensate and the steam taken from the turbogenerator are accelerated, thereafter mixing of the steam and the condensate is realized with the formation of the two-phase mixture of the condensate and steam with the transfer of the flow of the two-phase mixture to the supersonic flow conditions, then a sudden change of pressure is realized in the two-phase supersonic flow with the transfer of the two-phase flow during the sudden change of pressure into the single-phase liquid flow, here, at the same time, during the sudden change of pressure, the condensate is heated by an intensive steam condensation, and the condensate is heated additionally by collapsing the steam bubbles during the

sudden change of pressure, then the heated condensate is sent into the deaerator as feed water.

In case of an additional deceleration of the condensate in the jet apparatus, i.e., in the diffusor mounted at the outlet of the mixing chamber of the jet apparatus, has to be performed, the condensate is heated additionally. If a regulation of the heating conditions in a broad range is necessary, an installation of two or more jet apparatuses in parallel is possible. It is also possible to provide a multi-step system for heating the condensate by means of a stepwise bleeding of the vapour from one of its steps, with a stepwise feeding of the vapour into the jet apparatus ( for example, a jet heater of feed water). In this case, the bled vapour is fed in several subsequent steps downstream the condensate of the jet apparatus. Here, in each step, the acceleration of the liquid and vapour, the formation of the two-phase supersonic flow of the condensate and bled steam is realized, then in each step, a sudden change of pressure is accompanied by a transfer of the flow into a single-phase liquid subsonic one and simultaneously heating the liquid flow of the condensate is realized.

This object is also achieved in that the jet plant containing the jet apparatus with the receiving piece and receiving chamber, mixing chamber and the nozzle coaxially mounted thereto, the receiving piece is connected to the receiving chamber, in the plant, the confusor-diffusor (the converging channel and then downstream the diverging channel) bypass and the throttling element are provided, thereby the receiving piece is connected from its inlet side to the confusor section of the bypass, the mixing chamber is connected from its outlet side to the diffusor section of the bypass, the throttling element is mounted in the bypass between its confusor and diffusor sections, and the axis of the mixing chamber forms an acute angle with the axis of the bypass.

The throttling element can be mounted at the inlet of the diffusor section of the bypass, the confusor and diffusor sections of the bypass can be

connected to each other by a cylindrical pipe, several jet apparatuses can be connected to the bypass, and each one of these jet apparatuses can be rated at different power outputs.

In part for the method of operation of the jet plant, the object stipulated above is achieved by the method of operation of the jet plant, including feeding the hot heat carrier under pressure into the nozzle of the jet apparatus, its outflow from the nozzle and pumping the cold heat carrier with their subsequent mixing and the formation of the heated flow of the heat carrier mixture at the outlet of the jet apparatus. Thereby, the cold heat carrier is accelerated, and a part of the cold heat carrier is removed into the jet apparatus from the zone of its acceleration, and the remainder of the cold heat carrier is throttled after acceleration in the diverging downstream channel (a diffusor section) with the formation of a decreased pressure along the wall of this channel of the zone. The vapour is fed into the nozzle as the hot heat carrier, by mixing the vapour with the cold heat carrier, the two-phase flow is formed downstream the outflow section of the nozzle with the conversion of this flow in the supersonic flow, the latter one being decelerated with a conversion during the sudden change of pressure of the two-phase flow into the single-phase liquid heated flow of the heat carrier mixture, this flow is fed into the zone of decreased pressure, and boiling up is realized therein with a formation of the supersonic two-phase flow which is decelerated during mixing with the flow of the cold heat carrier in the diverging channel with the conversion of the two-phase flow into the liquid flow of the heat carrier, which is fed from the plant according to what it is determined for.

Realizing the process of mixing and heating of the liquid heat carrier in the jet apparatus during a sudden change of pressure being performed therein, in combination with the conversion of the flow into the two-phase flow and vice versa is possible. In the flow part of the jet apparatus, realizing the conditions by which the sudden change of pressure can be regulated and controlled, and consequently, the process of a transfer of the thermophysical

characteristics of medium flowing through the jet apparatus can be controlled, is possible.

In particular, the following relation has been shown:

$$\frac{P_2}{P_1} = k\beta M^2 + 1 = 1 + \frac{k\beta}{1 - \beta}$$

wherein $P_1$ - is the pressure before the sudden change of pressure;
$P_2$ - is the pressure during the sudden change of pressure;
$\beta$ - is the volume ratio of the vapour and liquid phases during the sudden change of pressure;
k - is the isentropic index of the homogeneous two-phase mixture;
M - is the Mach number in the mixture.

It has been found that the pressure before the sudden change of pressure and the pressure during the sudden change of pressure are mutually dependent values, and there is a certain relation between the pressure before the sudden change of pressure and the pressure during the sudden change of pressure determined by the isentropic index and the volume phase ratio in the mixture of the medium. This, in turn, allows a geometry of the jet apparatus required for the realization of the described method of operation to be developed, as well as by feeding and supplying the medium into the jet apparatus, by performing the process of mixing the medium in the jet apparatus to regulate the conditions of the medium flowing with an achievement of the result required by the object stipulated above.

It should be emphasized here that, in a known plant, in particular in the above-mentioned plant disclosed in the Russian Federation patent 2016261, the pressure before the sudden change of pressure was considered to be

independent from the pressure after the sudden change of pressure and to be equal to the saturation pressure at the mixture temperature.

In the new plant presented here, the pressure before the sudden change of pressure can be both, more than the saturation pressure at the mixture temperature, and, what is particularly important, less than the latter. This circumstance made the development of a plant possible, the realization of which was considered to be unreal previously. So, for instance, in the laboratory of the IBB company in Baden, investigations of a jet apparatus were carried out, in which the pressure of the steam and the water at the inlet of the device was lower than the atmospheric one. Here, the water pressure at the inlet was substantially lower than the saturation pressure at the mixture temperature, which, as it could be seen, made the movement of the liquid impossible in the flow part of the device. However, as the tests carried out have shown, the device operated stable, and the mixture pressure at the outlet of the jet apparatus was higher than the atmospheric one and was several times higher than the pressure at the inlet of the device.

One more principal difference of the new method of operation of the jet apparatus consists in that (refer to Fig. 5) in all known solutions including those, in which the sudden change of pressure was realized in the two-phase mixture, at first, the two-phase mixture (i.e., by performing the process of mixing or developing conditions for boiling up) was prepared, the volume ratio $\beta$ being less than 0.5. Here, the mixture movement was first subsonic, and then the mixture extended to sonic and supersonic velocity, and by increasing $\beta$, the flow velocity increased and the velocity of sound decreased simultaneously. The structure of the two-phase mixture before the sudden change of pressure was, as a rule, the bubble structure.

In the technical solution presented here, by abruptly boiling the liquid at the inlet or mixing the vapour and the liquid, the mixture before the sudden change of pressure had the volume ratio of medium essentially higher than

0.5 ($\beta > 0.5$), and for this reason, the flow is subsonic even at a large value of the flow velocity, and then, as a result of an influence of the profiled flow part of the jet device on the flow or of the realization of the process of mixing, the volume ratio of phases in the mixture decreases (the value $\beta$ decreases), the flow velocity decreases as well (proportionally to the decrease of $\beta$), the sound velocity drops sharply, and the sudden change of pressure, as a result of the above-described sequential influence on the flow, arises already at the inlet of the cylindrical part of the mixing chamber, and the sudden change in pressure can arise even in its conical part at unrated conditions.

Thus, it has been found possible to create conditions where the technical object stipulated is solved independently of the state of aggregation of the heated heat carrier, i.e., independently of whether it is in the liquid or vaporous state.

The conditions of the conversion of flows are of no lesser significance. In particular, it has been found that the embodiment in which the combination of the conversion of the two-phase supersonic flow into the single-phase one during the sudden change of pressure with the conversion of the two-phase flow in the critical flow velocity into the single-phase one without the sudden change of pressure with the formation of the liquid flow filled with microscopic vapour-gas bubbles was a preferred one. Collapsing of the vapour-gas bubbles allows an additional heating of the liquid flow to be reached without the supply of energy from outside by means of a more rational conversion of the flow energy.

In addition, the above-mentioned object was achieved by developing a jet apparatus, wherein the possibility to mix the flows of vapour and liquid and to form the two-phase mixture therefrom, which resulted in an abrupt decrease of the required velocity for performing the supersonic flow conditions, and only then to decelerate the supersonic two-phase flow, had been achieved. The latter, in turn, allowed as investigations have now

shown, two processes to be carried out at once; namely, to provide the transfer of the flow into the single-phase liquid one, and, secondly, to provide an additional heating of the liquid, since the heating process is provided by carrying out and performing two processes - the condensation of the vapour and collapsing of the vapour bubbles during the sudden change of pressure.

The construction of the jet plant with the bypass and the jet apparatus connected to each other in the way described above, allows the heating process to be performed such that the cold heat carrier goes directly through the bypass into the system of consuming of heat with minimum hydraulic losses, and only a strictly necessary portion of the cold heat carrier undergoes mixing with the hot heat carrier. Here, two-step mixing is actually realized, i.e., firstly, a portion of the cold heat carrier is mixed with the hot heat carrier in the jet apparatus, and then this mixture is mixed in the zone of the diffusor section of the bypass heat carrier with the remainder of the cold heat carrier. This allows a gently regulated system of heating of the cold heat carrier to be realized.

A mutual arrangement of elements of the construction of the plant is of benefit for its efficient operation.

The location of the axis of the mixing chamber at an acute angle to the axis of the bypass allows minimum energy losses to be achieved when mixing heat carriers.

The feed of the heat carrier mixture from the jet apparatus into the diffusor section of the bypass in combination with the location of the throttling element between the confusor and diffusor sections of the bypass, preferably at the inlet of the diffusor section, allows the heat carrier mixture to be fed from the jet apparatus into the zone of decreased pressure which is created by the throttling element along the wall of the diffusor section of the bypass. This allows the effect of boiling the flow to be achieved at the

point of the outflow of the flow of the heat carrier mixture into the diffusor section of the bypass with realizing the two-phase flowing zone and the transfer of the flow at supersonic flow conditions. A further flowing of the flow in the diffusor channel and its interaction with the main mass of the cold heat carrier leads to a resistance of the flow to the conversion of the flow into the single-phase liquid flow and the heating of the cold heat carrier by the energy of the hot heat carrier. The described method of mixing the heat carriers in the diffusor section of the bypass allows the process of heat exchange between the heat carriers in the rectilinear diverging downstream channel to be abruptly intensified, which allows the hydraulic energy losses to be decreased sharply. Here, the process of a feedback between the inlet confusor and outlet diffusor sections of the bypass is realized, because an increase of the pressure above the rated one inside the zone of the diffusor section will cause a pressure increase in the confusor section. This, in turn, will cause an increase of flow of entering cold heat carrier along the receiving piece into the receiving chamber of the jet apparatus with a pressure increase therein and a corresponding increase of the resistance to the outflow of the hot heat carrier from the nozzle, and, therefore, a decrease of its outflow. This will lead to a decrease of the power output of the jet apparatus and a decrease of the feed of the heat carrier mixture from the jet apparatus into the diffusor section of the bypass, leading to a pressure decrease therein. Thus, the plant will change to the self-regulation conditions without the use of additional means for maintaining the rated conditions of its operation set.

It is important to mention that the counter-pressure for apparatuses in which the sudden change of pressure takes place, is not the deceleration pressure at the inlet of the system, but a decreased pressure in the diffusor zone increasing an area of stable operation of the plant.

Another situation, in which the effect of self-regulation, and therefore, of stable operation of the plant manifests, is possible as well.

In case the feed pressure of the vapour (and therefore also its discharge) from the nozzle of the jet apparatus will decrease, the power output of the jet apparatus regarding pumping out the cold heat carrier will decrease. This will lead to a decrease of the feed of the heat carrier mixture into the diffusor section of the bypass. As a result, a decrease of the effect of the flow of the heat carrier mixture from the jet apparatus on the flow of the cold heat carrier will decrease. A more intensive pressure increase will take place in the diffusor channel, causing a decrease in the pressure differential at the throttling element with a decrease in the discharge of the cold heat carrier therethrough. Thus, the consumption of the cold heat carrier through the bypass will automatically decrease with maintaining the heating of the cold heat carrier in the given temperature range, as the vapour feed into the nozzle of the jet apparatus will decrease.

As has now been found, the most effective conditions of operation are achieved when using vapour as the hot heat carrier. Its use as the hot heat carrier allows the process of mixing the hot and cold heat carriers to be realized with the creation of the two-phase flow zone and with the transfer of the latter, by an abrupt decrease of the sound velocity therein during mixing to supersonic flow conditions. While decelerating the flow in the mixing chamber, preferably a confusor-cylindrical one, the sudden conversion of the flow from the two-phase one into the single-phase occurs during the sudden change of pressure, a homogeneous one regarding temperature, liquid flow. It was shown that a maximum efficiency of the operation of the jet apparatus could be achieved, when connecting the receiving piece to the bypass in the zone of its confusor section.

One method of broadening the range of the use of the plant is providing the plant with several jet apparatuses, preferably of different power output. This allows a plant to be developed stably operating in a broad temperature range without a decrease of the operation efficiency of the plant.

Thus, the realization of the technical object is achieved by entering the medium into the jet apparatus in the above-described method.

**Brief description of the drawings**

Fig. 1 shows schematically the flow part of a jet apparatus according to the present invention when realizing the described method of operation of the jet apparatus.

Fig. 2 shows schematically a section of a jet apparatus of the present invention, in particluar the heater of the feed water.

Fig. 3 shows one scheme of connecting a jet apparatus of the present invention being a part of an energy plant in which the described method of regenerative heating of the feed water is described.

Fig. 4 shows schematically another embodiment of the jet plant.

**Modes for Carrying Out the Invention**

The jet heat emitting apparatus for realizing the described methods, according to Fig. 1, contains a nozzle 1, a receiving chamber 2 with a profiled outlet section 3, a mixing chamber 4 and a diffusor 5.

The plant for realizing the described method (refer to Fig. 3) contains a deaerator 6, a turbogenerator 7, a jet apparatus - a jet heater of feed water 8, an automatic regulator 9 for bypassing the condensate, a control block 10 and slide-valves 11 with an electric drive controlled by the control block 10.

Fig. 2 shows the pressure change of the fed steam and condensate along the flow part of the jet apparatus 8 of the system of Fig. 3.

Referring to Fig. 4, the jet plant comprises a jet apparatus 12 with a receiving piece 13 and a coaxially arranged receiving chamber 14, a mixing chamber 15 and a nozzle 16, here the receiving piece 13 is connected to the receiving chamber 14. The plant additionally contains a confusor-diffusor bypass 17 and a throttling element 18. The receiving piece 13 is

connected from the side of its inlet to a confusor (converging downstream of the heat carrier flow) section 19 of the bypass 17, the mixing chamber 15 is connected from the side of its outlet to a diffusor (diverging downstream of the heat carrier flow) section 20 of the bypass 17. The throttling element 18 is mounted in the bypass 17 between its confusor 19 and diffusor sections 20, and the axis of the mixing chamber 15 forms an acute angle $\alpha$ with the axis of the bypass 17. The throttling element 18 can be mounted at the inlet of the diffusor section 20 of the bypass 17. The axis of the receiving socket 13 can form a right angle $\phi$ with the axis of the mixing chamber 15. The confusor and diffusor sections 19, 20 of the bypass 17 can be connected to each other by a cylindrical pipe 21. Several jet apparatuses 12, which can have different power outputs, can be connected to the bypass 17.

According to Fig. 1, the jet heat emitting apparatus operates as follows.

In case a liquid medium, such as water, is used as the heated heat carrier, this medium is fed under pressure into the nozzle 1. The heated liquid heat carrier is accelerated in the nozzle 1 and, by flowing out of it, carries along the cold heat carrier into the jet apparatus and mixes it therewith. The heat carrier mixture at the inlet of the mixing chamber 4 is accelerated to a velocity at which at least one of the heat carriers (in cases in which the heated and cold heat carriers have different physical properties which is possible at different steps of the operation of the plant) boils with the formation of the two-phase vapour-gas-liquid flow by changing of the latter, to supersonic flow conditions. The above-described processes are accompanied by a pressure change in the heat carrier flow. When the heated heat carrier flow enters the nozzle 1, the flow narrows, leading to an increase of kinetic energy of the flow and a decrease of pressure (sections I-I and II-II). Analogously, a similar picture in the flow of the cold heat carrier can be observed at the flow in the profiled outlet section 3 of the receiving chamber 2. While mixing the flows of the heated and cold heat carriers in the mixing chamber 4, their velocities, temperature and

pressure equalize with the transfer of a portion of kinetic and thermal energies from the heated heat carrier to the cold heat carrier. In the narrowing flow part of the mixing chamber 4, the acceleration of the heat carrier mixture accompanied by a subsequent pressure drop (section III-III) continues. As mentioned above, the velocity is subjected to acceleration, at which point the heat carrier will boil as a result of the drop of pressure below the pressure of saturated vapour of the heat carrier mixture or at least of one heat carrier. This leads to the formation of the two-phase flow, the velocity of which increases sharply, and the value of the velocity, at which the supersonic flow conditions are set, drops. Because of this, the supersonic conditions of the flow are set. This, in turn, causes the sudden change of pressure (sections III-III, IV-IV). During the sudden change of pressure, the two-phase flow transforms sharply into the single-phase liquid subsonic flow. Here, such a sharp change of the state of phase flow is accompanied simultaneously by heating the flow during the sudden change of pressure. Then, in the mixing chamber 4, the liquid flow of the heat carrier mixture between the sections IV-V is accelerated repeatedly to the velocity at which at least one heat carrier boils by the formation of the two-phase flow, the Mach number of which is equal to 1 (near section V). Then in the flow, the conversion of the two-phase flow of the heat carrier mixture into the liquid flow of the heat carrier mixture filled with microscopic vapour-gas bubbles is realized. Here, as during the sudden change of pressure, the second conversion of the flow is accompanied by its further heating. Following the above-mentioned conversions, the flow of the heat carrier mixture is fed to a consumer, either under the pressure obtained after the second conversion, or under the pressure obtained in the diffusor 5. It should be especially mentioned that neither the combination of the above-described conversions of the flow of the heat carrier mixture, nor their sequence is essential. Because of this, the same result can be achieved by changing the places of the two above-described conversions of the flow of the heat carrier mixture, i.e. by carrying out at first the conversion of the flow into the two-phase one by setting critical flow conditions (the velocity of the flow at which the Mach number is equal to 1) with the subsequent

conversion of the two-phase flow into the liquid one filled with the vapour-gas bubbles, and then by carrying out the conversion into the two-phase supersonic flow with the subsequent transfer into the liquid flow during the sudden change of pressure.

Other embodiments of the method of operating the jet heat emitting apparatus differ mainly from the above-described method in that a vapour, such as steam or water vapour, is fed into the nozzle 1 of the jet apparatus as the heated heat carrier. As a consequence of such a transfer of the state of aggregation of the heated heat carrier, the process of heating the cold heat carrier by a transfer of a larger amount of heat to it, as well as the process of the formation of the two-phase flow is intensified. Here, as described above, two conversions are carried out in the flow, i.e., the conversion of the flow of the heat carrier mixture by realizing the sudden change of pressure and the conversion of the flow of the heat carrier mixture with setting the critical flow conditions. An essential difference consists in that the conversion of the flow of the heat carrier mixture carried out first does not require a special acceleration of the heat carrier mixture for boiling of at least one of them, which also allows the process of the heating of the heat carrier mixture to be accelerated.

Thus, these embodiments include the following operations: feeding of the heated heat carrier-steam into the nozzle 1 under pressure, its outflow from the nozzle 1 with entering of the cold heat carrier into the mixing chamber 4 from the receiving chamber 2 and the formation of the two-phase vapour-gas-liquid flow of the heat carrier mixture in the mixing chamber 4 behind the nozzle 1 during mixing the heat carriers. The difference between these embodiments of the method of operation consists in the following. In one embodiment, the vapour-gas-liquid flow is converted first into the supersonic flow, and the sudden change of pressure is realized in the latter with the conversion in this sudden change of pressure of the two-phase (vapour-gas-liquid) flow into the single-phase subsonic liquid flow with the heating of this flow of the heat carrier mixture during the sudden change of pressure. Then

the acceleration of the liquid flow to the velocity at which at least one heat carrier will boil is realized, and the flow conditions of the two-phase flow with the Mach number equal to 1 are set. Thereafter, by decelerating the flow, its transfer to the liquid flow of the heat carrier mixture filled with microscopic vapour-gas bubbles with additional simultaneous heating of the liquid flow of the heat carrier mixture, as the flow is decelerated, and with a pressure increase in the flow is realized. Then the heated liquid flow of the heat carrier mixture is fed to the consumer under the obtained pressure.

Another embodiment of the method of operation with the feeding of vapour, for example steam, into the nozzle 1 differs from the above-described one by the following features. Firstly, the flow conditions of the vapour-gas-liquid flow of the heat carrier mixture with a Mach number equal to 1 and corresponding conversions of the flow distinctive therefor are set, and then boiling the flow with setting the supersonic flow conditions and with correspondingly above-described conversion characteristics for these flow conditions is realized.

The described method of regenerative heating of the feed liquid, for example water, is realized as follows.

The realization of the applied method of operation of the jet apparatus is shown in the example of the multi-step way of feeding the bled vapour. The start of the system of regenerative heating is accomplished by feeding vapour into the last step (between sections V and VI in Fig.2) of one or two (with a minimum load) jet apparatuses 8. The condensate fed from the condenser (not shown) and the steam bled from the turbogenerator 7 between sections V and VI are accelerated and mixed with each other. Here, in section VI, the flow velocity of the mixture of the medium reaches a maximum value, and the pressure in the flow drops to a minimum value, which causes the realization of the supersonic flow conditions of the two-phase flow. In the two-phase flow, the value of the velocity of sound drops sharply, and this promotes the realization of the supersonic flow conditions.

For in section VI, by decelerating the flow in the two-phase supersonic flow, the sudden change of pressure is realized to a pressure increase up to the value $P_2$. Here, as a result of the intensive vapour condensation during the sudden change of pressure, as well as a result of the process of collapsing of vapour bubbles accompanied by an instantaneous increase of the pressure of the vapour in the collapsing bubbles thousands of times, during the sudden change of pressure heating of liquid and the conversion of the two-phase flow into the liquid single-phase flow of the heated (warmed) liquid occur. This liquid is fed under pressure as the feed liquid from the jet apparatus 8 into the deaerator 6. The realization of the above-described processes of the acceleration of the liquid and vapour and their subsequent mixing between sections V and VI simultaneously causes a pressure decrease in the previous step of the jet apparatus 8 (sections II-IV in Fig. 2). This simplifies starting the vapour in this step, and therefore starting of this step. In this step, the above-described processes of acceleration, mixing, realization of supersonic flow conditions, deceleration, pressure increase and heating of the liquid are realized. Although the pressure increase is not stepwise, as it is shown in Fig. 2, however, in section VI, the outflow conditions are critical ($M = 1$). After the starting of the first step of the jet apparatus 8, the latter changes to the regular operation conditions for the heating the feed liquid. When increasing the load at the turbogenerator 7 (an increase of the vapour discharge at the turbine), the liquid level in the deaerator 6 decreases. A command for opening the automatic regulator 9 is sent through the control block 10, and this causes entering an additional amount of feed liquid to enter the deaerator 6. When decreasing the load at the turbogenerator 7 and, therefore, increasing the liquid level in the deaerator 6, after the signal of the block 10, the feed of the liquid through the automatic regulator 9 decreases. Thus, stable conditions of the operation of jet apparatuses 8 are provided by bypassing the liquid.

In connection with the above description, it is to be dwelt on the algorithm of the automatic regulation of the operational conditions by the control block 10 (see Fig. 3). The latter provides for a constant regulation of the capacity

by successive switching on and switching off the jet apparatuses 8 depending on the change of the load at the turbogenerator 7. The constant regulation also provides the continuous regulation of the discharge through the automatic regulator 9, and namely, a decrease of the discharge therethrough when decreasing the load at the turbogenerator 7, and an increase of the discharge when increasing this load. Thereby, the constant pressure differential at one or several (depending on the operation conditions) jet apparatuses 8 is maintained.

In the initial conditions, the automatic regulator 9 is in the intermediate (middle) position allowing a smooth regulation of the liquid level in the deaerator 6 to be provided by changing the ratio of the amount of the heated liquid in the jet apparatuses 8 and the liquid (condensate) entering through the automatic regulator 9. The maximum discharge consumption or respectively by the liquid through the automatic regulator 9 is chosen as one equal to the discharge through the jet apparatuses 8 (in this case, to the discharge of the two jet apparatuses 8). As it was noted above, at first, one jet apparatus 8 providing the required level of the heating of the liquid is started (though it is not excluded that several jet apparatuses 8 can be started at once). When the discharge of the liquid from the deaerator 6 increases (the increase of the load at the turbogenerator 7 requires a larger amount of the feed liquid for the production of the vapour), the liquid discharge through the automatic regulator 9 gradually reaches its maximum value (maximum opening of the regulator 9). Then, after the signal from the automatic regulator 9, the control block 10 gives the command for opening the slide-valve 11 at the outlet of the second jet apparatus 8, and the second jet apparatus 8 is started. The automatic regulator 9 returns to the middle position. Subsequently, when the load at the turbogenerator 7 decreases, the level of the liquid medium in the deaerator 6 begins to increase, and then, after the signal of the control block 10, through the automatic regulator 9, the condensate discharge is decreased. If the regulator 9 reaches its lower limit (it will be closed), after the signal of the same control block 10, the slide-valve 11 at the second jet apparatus 8 is

closed, and this apparatus is stopped. The automatic regulator 9 is switched over at the same time to its middle position. Thus, the feed of the condensate through the bypass line through the automatic regulator 9 and successive switching on and switching off, parallel jet apparatuses 8 provide a smooth regulation of the level of the heated feed liquid in the deaerator 6.

It is also possible to regulate the intensity of the sudden change of pressure in the jet apparatuses 8 by increasing or decreasing the feed of the vapour in the jet apparatuses 8, and respectively, to regulate the heating conditions of the feed vapour. A parallel installation of several jet apparatuses 8 allows the operation reliability of the whole system of the heating of the feed liquid to be increased, for in the case of disabling, for some reason, one of the jet apparatuses 8, it can be switched off, and other apparatuses 8 will continue to perform their functions. In addition, by transferring the vapour from the disabled apparatus 8 to other jet apparatuses 8, a missing heating of the feed liquid can be compensated for by increasing the intensity of the sudden change of pressure therein. Because of this, idle operation of the turbogenerator is prevented, allowing considerable losses to be avoided.

The realization of the above-described method of operation is now considered by describing the operation of the jet plant shown in Fig. 4 using steam.

Steam is fed into the nozzle 16. At the same time, the bypass 17 is connected to the source of the cold heat carrier at the side of the inlet in its confusor section 19. The steam, when flowing out from the nozzle, carries along the cold heat carrier into the mixing chamber 15 from the bypass 17 through the receiving piece 13. Mixing the steam and the cold heat carrier results in a partial transfer of kinetic energy and the heat of the steam to the latter with the formation of the two-phase steam-liquid flow behind the outlet of the nozzle 16. Mixing results in a decrease of the velocity of sound in the two-phase flow, the latter changing to the supersonic flow conditions

with subsequent flow deceleration in the confusor channel of the mixing chamber 15 and the conversion of the two-phase supersonic flow into the single-phase subsonic liquid heated flow of the heat carrier mixture during the sudden change of pressure. The heated flow of the heat carrier mixture flows out through, preferably, a cylindrical outlet section of the mixing chamber 15 into the diffusor section 20 of the bypass 17. Here, the section of the inlet of the cylindrical piece or socket, respectively, of the mixing chamber 15 should be located as near as possible to the outlet section of the throttling element 18. At the same time, the cold heat carrier is accelerated in the confusor section 19 of the bypass 17 and, by flowing out through the throttling element 18 into the diffusor section 20, forms along its wall in the zone of outflow of the flow of the heat carrier mixture from the jet apparatus 12, the zone of decreased pressure 22 therein. As a result thereof, when the heated flow of the heat carrier mixture flows out in the zone of decreased pressure 22, it boils with the formation of the two-phase steam-gas-liquid flow with its transfer by mixing with the cold heat carrier, which is critical at the outlet of the cylindrical section ($M=1$), to the supersonic flow conditions. The interaction of the two-phase flow with the cold heat carrier in the diffusor section 20 results in the deceleration of the supersonic flow and its transfer to subsonic flow conditions. Here, in the process as described above, conversions of the two-phase flow into the single-phase liquid flow, the hot heat carrier transfers a portion of its thermal and kinetic energy to the cold heat carrier. The heated flow of the heat carrier mixture enters from the diffusor section 20, according to its destination, to a consumer of thermal energy.

The described methods of operation of jet heat emitting apparatuses can be realized both, in systems of centralized production of heat and electricity, and when creating an autonomous heat emitting plant, e.g., systems for heating of premises of different kinds, where systems of centralized heating are absent, including those in northern regions, as well as for heating cottages and datshas. In addition, there is a possibility to develop a

stationary plant of jet heaters conversing effectively energy of liquid and vaporous heat carriers when heating "cold" heat carriers.

The method and apparatus of the present invention may be employed in situations in which the heating of a feed stream is required. Examples of such applications are to be found in the chemical processing industry and in the processing of foodstuffs, for example the pasturisation of milk and like products.

Claims

1. A method of operation of a jet apparatus, including feeding at least one liquid heat carrier under pressure into a nozzle, feeding of a cold liquid heat carrier and their mixing, **characterized in that** two conversions are carried out with the liquid flow of the heat carrier mixture, one of them including an acceleration of the heat carrier mixture to a velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of a two-phase flow with the transfer of the latter to conditions with a Mach number of more than 1, and then a sudden change of pressure with the transfer in the latter of the two-phase flow to a subsonic liquid flow of the heat carrier mixture and heating the liquid flow of the heat carrier mixture during the sudden change of pressure being performed; another conversion including the acceleration of the liquid flow of the heat carrier mixture to a velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two-phase flow with the transfer of the latter to the conditions with a Mach number equal to 1, then the two-phase flow being decelerated, and thereby the flow being converted into the liquid flow of the heat carrier mixture with vapour-gas bubbles, and additionally, by this flow conversion, the liquid flow of the heat carrier mixture being heated; thereafter carrying out said two above-mentioned conversions of the liquid flow of the heat carrier mixture in any sequence, the heated liquid flow of the heat carrier mixture being fed under the pressure obtained in the jet apparatus to a consumer.

2. The method according to claim 1, characterized in that one or several conversions with the liquid flow of the heat carrier mixture are carried out additionally.

3. A method of operation of a heat emitting jet apparatus including feeding a heated liquid carrier under pressure into a nozzle, feeding of a cold liquid heat carrier and their mixing, **characterized in that** a vapour is fed into the nozzle as said heated heat carrier with the formation of the two-phase flow in the process of mixing with the cold heat carrier by the vapour behind the nozzle, flow conditions of the two-phase flow with a Mach number of more than 1 being established, thereafter, a sudden change of pressure with a conversion of a supersonic two-phase flow into a single-phase liquid flow of the heat carrier mixture therein, and simultaneously heating the heat carrier mixture during the sudden change of pressure being performed; thereafter, the flow of the heat carrier mixture being accelerated to a velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two-phase flow, the flow conditions of the two-phase flow with a Mach number equal to 1 being established; then by means of a deceleration of the flow, its conversion into the liquid flow of the heat carrier mixture with vapour-gas bubbles with an additional heating of the liquid flow of the heat carrier mixture and a pressure increase in the flow as the flow is decelerated, being realized; and thereafter, the heated liquid flow of the heat carrier mixture being fed to a consumer under the pressure obtained in the jet apparatus.

4. A method of operation of a heat emitting jet apparatus, including feeding of a heat carrier under pressure into a nozzle, feeding of a cold liquid heat carrier and their mixing, **characterized in that** a vapour is fed into the nozzle as said heated heat carrier with the formation, by the vapour behind the nozzle, of a two-phase flow in the process of mixing with the cold liquid heat carrier, flow conditions of the two-phase flow with a Mach number equal to 1 being established; then the two-phase flow being decelerated and thereby converting into the liquid flow of the heat carrier mixture with vapour-gas bubbles with the heating of the flow in the process

of its conversion into the liquid one and pressure increase in the flow; thereafter, the flow of the heat carrier mixture being accelerated to a velocity at which the heat carrier mixture or at least one of the heat carriers of the mixture boils with the formation of the two-phase flow, then the flowing conditions of the two-phase flow with a Mach number of more than 1 being established; the two-phase flow of the heat carrier mixture during the sudden change of pressure being converted into the liquid flow of the heat carrier mixture with an additional heating of the liquid flow of the heat carrier mixture during the sudden change of pressure; thereafter, the heated liquid flow of the heat carrier mixture being fed to a consumer under the pressure obtained in the jet apparatus.

5. A method of regenerative heating feed water in a jet heater, including feeding of steam into a turbogenerator, bleeding the steam from the turbogenerator, removal of bled steam from the turbogenerator in a condenser, feeding of condensate from the condenser and the steam bled from the turbogenerator in the jet apparatus with condensation of steam in the jet apparatus and by heating the condensate with subsequently feeding the heated condensate as feed water into a deaerator, and then into a boiler-steam generator, **characterized in that** the condensate and the steam bled from the turbogenerator are accelerated, thereafter mixing of the steam and condensate with the formation of a two-phase mixture of the condensate and steam with the transfer of the flow of the two-phase mixture to the supersonic flow conditions being realized, then a sudden change of pressure being realized in a two-phase supersonic flow with the transfer of the two-phase flow during the sudden change of pressure by collapsing of steam bubbles and by an intensive steam condensation, into the single-phase liquid subsonic flow, the condensate being heated at the same time by an intensive steam condensation in the condensate; and being additionally heated by collapsing of steam bubbles during

the sudden change of pressure; and then the heated liquid flow of the condensate being sent into the deaerator.

6. The method according to claim 5, characterized in that the liquid flow of the condensate is additionally decelerated in the jet apparatus, and thereby the liquid flow of the condensate is additionally heated.

7. The method according to claim 5, characterized in that a multi-step feed of the steam into the jet apparatus by means of successive stepwise bleeding of the steam from several stages of the turbogenerator is realized, and in each step of the jet apparatus the formation of the two-phase mixture of the condensate and steam with the transfer of the flow to the supersonic flow conditions and the realization of the sudden change of pressure in each step with the transfer of the flow into the single-phase liquid one and simultaneously heating the liquid flow of the condensate is realized.

8. A jet plant containing a jet apparatus with a receiving piece and coaxially arranged a receiving chamber, a mixing chamber and a nozzle, with the receiving piece being connected to the receiving chamber, **characterized in that** in the plant, a confusor-diffusor bypass and a throttling element are provided, the receiving piece being connected from its inlet to a diffusor section of the bypass, the mixing chamber being connected from its outlet to a diffusor section of the bypass, the throttling element being mounted in the bypass between the confusor and diffusor sections, and the axis of the mixing chamber forming an acute angle with the axis of the bypass.

9. The plant according to claim 8, characterized in that the throttling element is mounted at the inlet of the diffusor section of the bypass.

10. The plant according to claim 8, characterized in that the confusor and diffusor sections of the bypass are connected to each other by a cylindrical pipe.

11. The plant according to claim 8, characterized in that several jet apparatuses are connected to the bypass.

12. The plant according to claim 8, characterized in that the jet apparatuses connected to the bypass are of different power output.

13. A method of operation of a jet plant, including feeding of a hot heat carrier under pressure into a nozzle of the jet apparatus, its outflow from the nozzle and by pumping out a cold heat carrier with their subsequent mixing and formation of a heated flow of the heat carrier mixture at an outlet of the jet apparatus, **characterized in that** the cold heat carrier is accelerated, a portion of the cold heat carrier is removed into the jet apparatus from the zone of its acceleration, the remainder of the cold heat carrier is throttled after acceleration in a diverging downstream channel with the formation of a decreased pressure along the wall of the channel of the zone; a vapour being fed into the nozzle as the hot heat carrier, during mixing of the vapour with the cold heat carrier, the two-phase flow is formed behind an outflow section of the nozzle with a conversion of this flow into a supersonic flow, the latter are decelerated with a conversion during the sudden change of pressure of the two-phase flow into a single-phase liquid heated flow of the heat carrier mixture, this flow being fed into the zone of the decreased pressure, and boiling being realized therein with a formation of the supersonic two-phase flow, which is decelerated during mixing with the flow of the cold heat carrier in the diverging channel with the conversion of the two-phase flow into the liquid flow of the heat carrier.

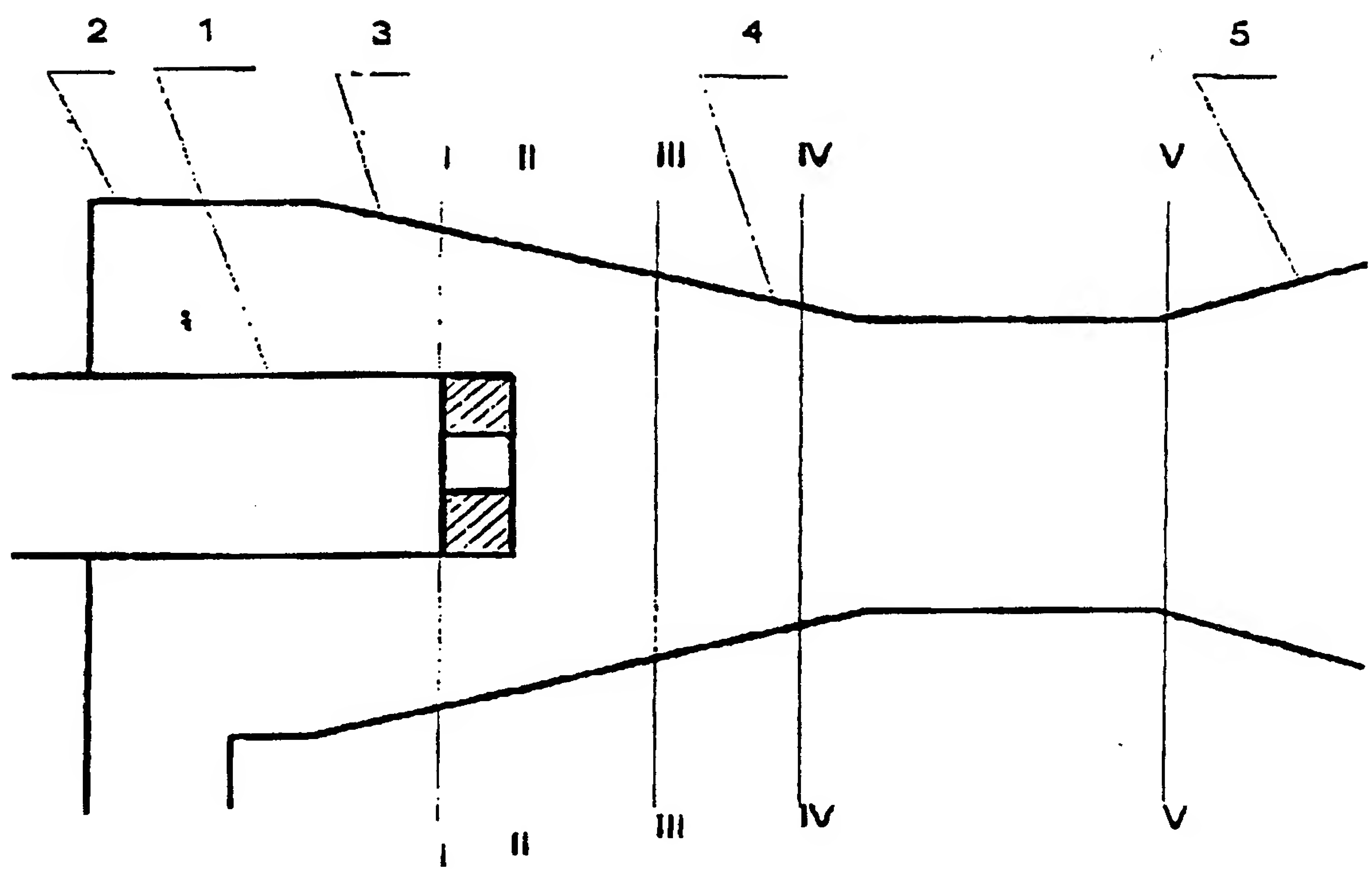


FIG. 1

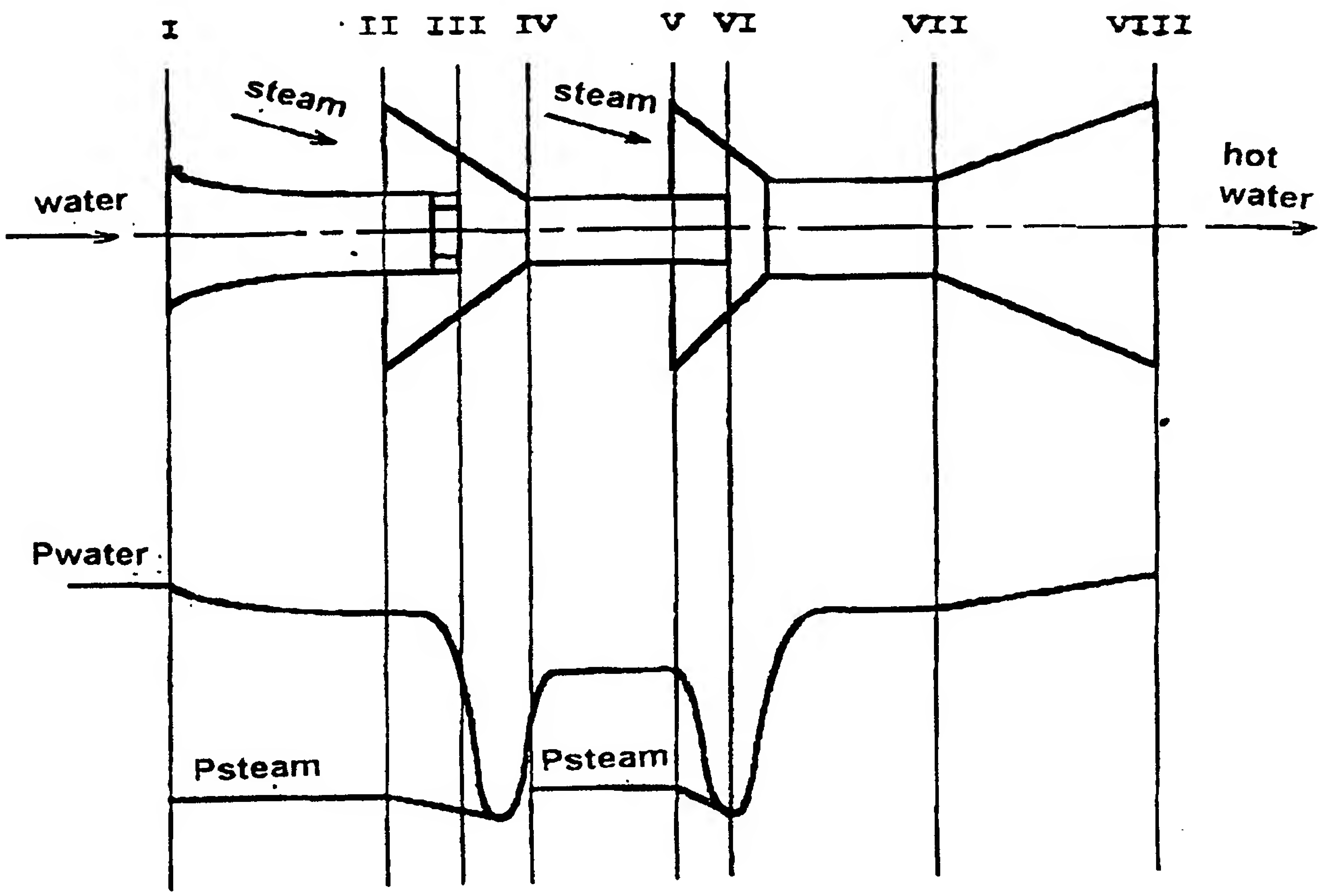
I
II
III
IV
V
VI
VII
VIII
steam
steam
water
hot
water
Pwater
Psteam
Psteam

FIG. 2

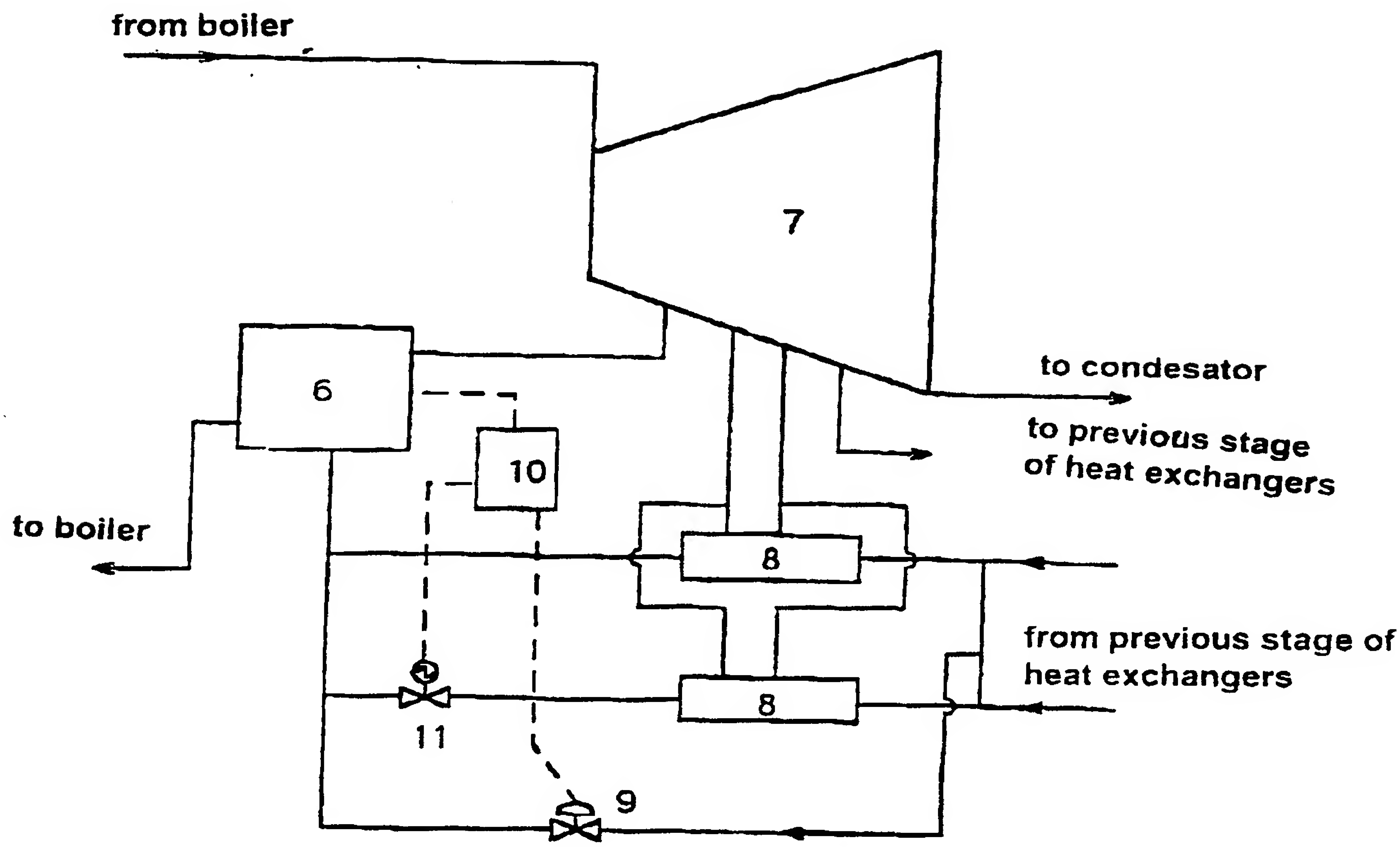
from boiler
7
6
10
to condesator
to previous stage
of heat exchangers
to boiler
8
8
from previous stage of
heat exchangers
11
9

FIG. 3

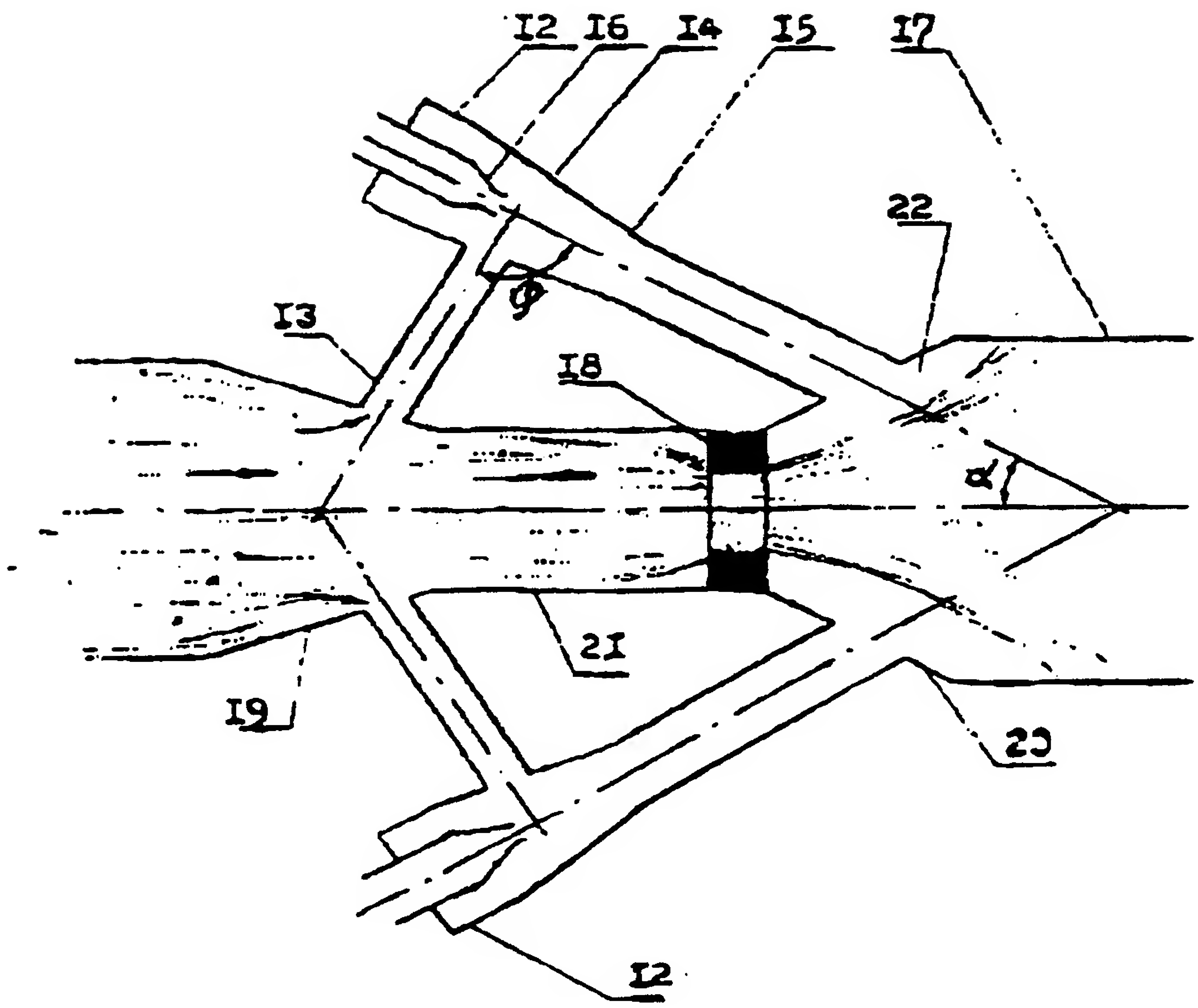


FIG. 4

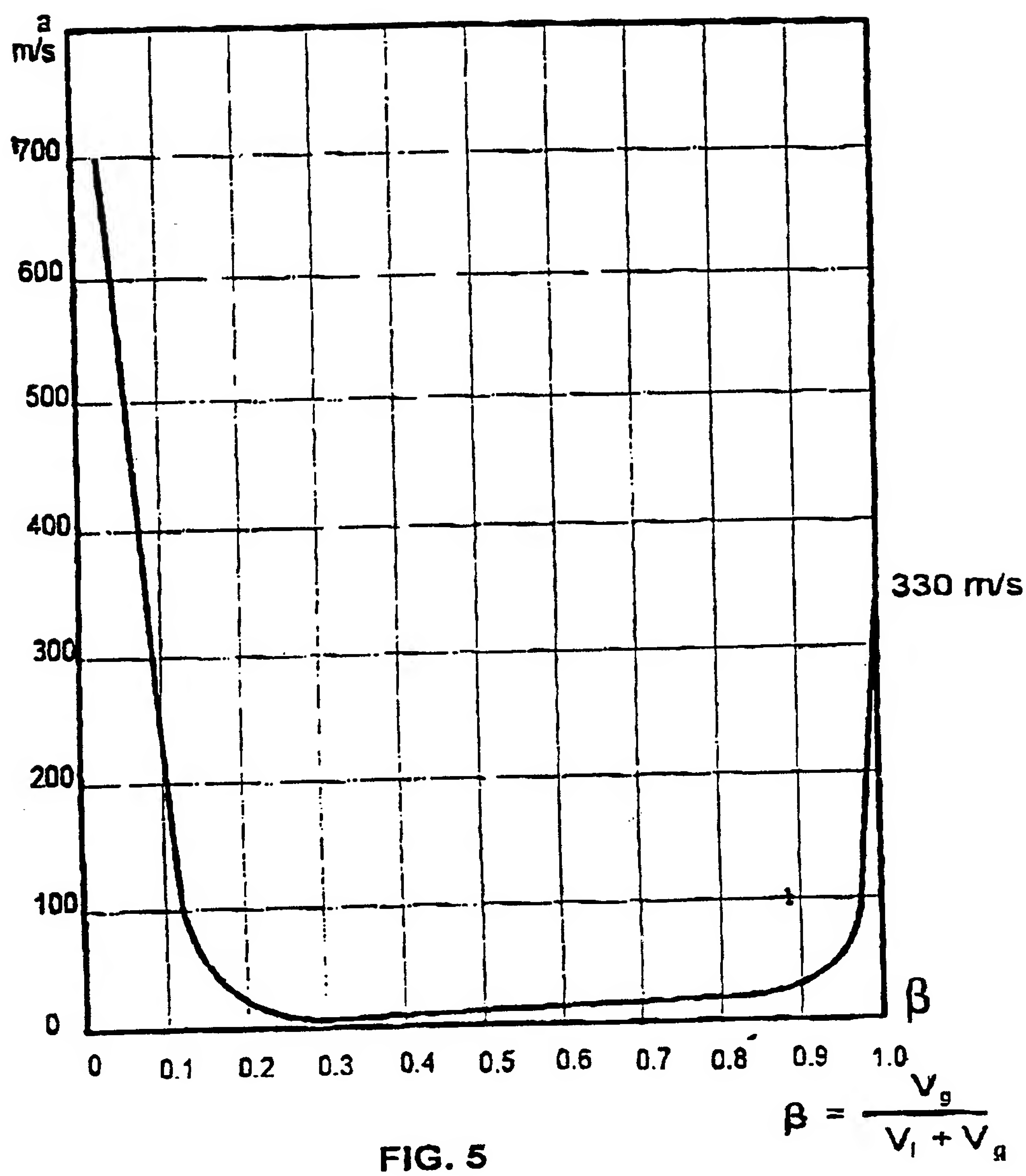
a
m/s
700
600
500
400
300
200
100
0
330 m/s
β
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
$\beta = \frac{V_g}{V_l + V_g}$

FIG. 5

# INTERNATIONAL SEARCH REPORT

Int tional Application No
PCT/US 98/05275

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 B01F5/04 F04F5/24 F04F5/48

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F04F B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| X | US 3 200 764 A (SAUNDERS, ROBERT C.) 17 August 1965 | 8 |
| Y | see column 2, line 14 - line 19<br>see column 3, line 1 - column 4, line 27<br>see figure 1<br>--- | 13 |
| X | US 5 544 961 A (FUKS EFIM ET AL) 13 August 1996 | 8-10 |
| Y | see column 2, line 46 - line 54<br>see column 2, line 66 - column 3, line 23<br>--- | 13 |
| | -/-- | |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 October 1998 | 26/10/1998 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Jungfer, J |

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International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

| International Application No |
|---|
| PCT/US 98/05275 |

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